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SECTION OF GEOLOGY AND MINERALOGY[1]

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PROFESSOR MARLAND P. BILLINGS, Department of Geology and Geography, Harvard University, Cambridge, Mass.: *Ring-dikes and Their Origin.* (This lecture was illustrated by lantern slides and maps.)

INTRODUCTION

An *annular intrusive body* is one that is circular, oval or arcuate in plan. This is a rather general term that includes ring-dikes, cone sheets and other bodies. A *ring-dike* is a discordant, intrusive body that is circular, oval or arcuate in plan and has steep contacts. The annular shape is essentially that which the body possessed originally. A *ring-dike complex* is a structural unit containing one or more *ring-dikes*. *Cauldron subsidence* is a process involving the sinking of a cylindrical or paraboloidal block between steep walls. The resulting structure is also called a cauldron subsidence. Cauldron subsidence may result in the formation of one or more ring-dikes but the process does not necessarily lead to the formation of ring-dikes. Moreover, ring-dikes may form without cauldron subsidence, as will be shown below. Daly (1933, p. 269) uses the term *ring-fracture stoping* in preference to cauldron subsidence. It is apparent that the terms ring-dike, annular intrusive body, and cauldron subsidence are not synonymous.

[1]No meeting was held in March by the Section of Biology. See page 155 for announcement of Conference on "*Parasitic Diseases and American Participation in the War.*"

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Although the term ring-dike was first used by E. B. Bailey (1914), the fundamental ideas were evolved in a study at Glen Coe, Scotland (Clough, Maufe and Bailey, 1909). The studies at Mull (Bailey, *et al.*, 1924) also contributed to the concept of ring-dikes.

SIGNIFICANT DATA

Introduction.—The writer has assembled data for 115 ring-dikes from 30 ring-dike complexes in different parts of the world. In making such a study from geological publications, an investigator is faced with many difficulties. Although in some instances the published descriptions are complete and fully adequate, in others the data are insufficient for a satisfactory analysis.

Distribution.—Ring-dikes are extensively developed only in the British Isles and New Hampshire. They are undoubtedly present in the Oslo district of Norway, and may be common there. One ring-dike complex has been reported from Colorado and one ring-dike each has been reported from Utah, California, and Texas. Two ring-dikes reported from India and North Carolina have not been included in the present analysis, because the publications were not available to the writer.

Number of Ring-dike Complexes.—Approximately 30 ring-dike complexes have been described or are implied by geological maps. Eight of these complexes occur in the British Isles (four are Tertiary and four are Devonian); 15 occur in New Hampshire and adjacent areas; three occur in the Oslo district, Norway; one ring-dike complex each occurs in Utah, California, Texas and Colorado.

The data for the Oslo district are based on a study by the writer of geological maps. Holtedahl (1935) has shown that ring-dikes are present in the Oslo region but he gave very little detailed information.

Number of Ring-dikes.—Approximately 115 ring-dikes are known. Again it is difficult to be precise because in some instances it is rather arbitrary whether a structural unit should be considered a single ring-dike, made up of several separate intrusions, or whether it should be considered as several discrete ring-dikes. Fifty-nine ring-dikes have been described from the British Isles and 41 from New Hampshire and adjacent regions. At least 10 ring-dikes seem to be present in the Oslo region, probably more. Five ring-dikes have been described from the western United States.

The number of ring-dikes in a ring-dike complex differs greatly.

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In many ring-dike complexes only one ring-dike occurs. On the other hand, in Ardnamurchan on the west coast of Scotland, 23 ring-dikes are found in a single ring-dike complex (Richey, Thomas, *et. al.*, 1930).

PLAN.—Very few ring-dikes form complete circles in plan. The average ring-dike forms a semicircle that encompasses about 180 degrees. Those that are complete encompass 360 degrees; an example of such is found in the Ossipee Mountains of New Hampshire (Kingsley, 1931). One ring-dike encompasses only 20 degrees of the possible 360 degrees.

No ring-dike is strictly circular in plan. In many instances there is a tendency to be elliptical, and all ring-dikes show irregularities to a greater or lesser extent.

RADIUS.—The radius of a ring-dike can be measured either to the outer or inner margin. On the whole, it seems best to measure the radius to the outer margin. The average radius of ring-dikes is 2.3 miles. The minimum value is about a thousand feet, whereas the maximum value, found in a ring-dike in the Franconia Quadrangle in New Hampshire, is 7.5 miles (Williams and Billings, 1938).

WIDTH.—The average width of ring-dikes, measured from the inner to the outer contacts, is 1600 feet; the maximum is 14,000 feet, in the Franconia Quadrangle, New Hampshire.

ATTITUDE OF CONTACTS.—It is highly important to know the attitude of the contacts of ring-dikes. Unfortunately, comparatively few data are available on this critical subject. It is clear that in many cases the field geologists have been unable to obtain this information despite assiduous search. In other cases, the published reports do not state clearly what data could be obtained. All together, about 43 observations on the attitude of the contacts have been recorded in publications. The average dip is 78 degrees outward. The lowest outward dip that has been observed is 33 degrees, found in the Belknap Mountains of New Hampshire (Modell, 1936). In many cases, the contacts are vertical and in a few instances inward. A dip of 78 degrees inward has been observed in the Percy Quadrangle, New Hampshire (Chapman, 1935).

DISCORDANT RELATIONS.—Many ring-dikes have been intruded into massive older plutonic rocks and thus it is impossible to determine whether the ring-dike is discordant or concordant. In some instances, however, the ring-dikes clearly cut across the structure of the older rocks. Some of the best examples of discordant relations are found in Norway.

Shifting of Center.—Within a single ring-dike complex there may be more than one center about which the ring-dikes are concentric. Several ring-dikes may be concentric about one center. Other ring-dikes within the same complex may be concentric about a second center one or two miles away from the first. In general it seems that in Scotland the various centers within a ring-dike complex operated successively. That is, the earliest ring-dikes were intruded around one center. Then another center was established, and all ring-dikes intruded during this second stage were concentric about the second center. If a third center developed, the youngest ring-dikes were concentric about it. In New Hampshire, on the other hand, there is considerable evidence that two or more centers within the same ring-dike complex were operating simultaneously.

Associated Ring-fault.—It is believed that the intrusion of each ring-dike was preceded by the formation of a fracture. In some instances, it is possible to demonstrate that this fracture was a fault more or less circular in plan. The existence of a ring-fault has been demonstrated in at least three localities: Glen Coe (Clough, Maufe, and Bailey, 1909), Mull (Bailey, 1924, p. 340), and Belknap Mountains (Modell, 1936, pp. 1918–1922).

Composition.—Ring-dikes show a wide range in the rocks of which they are composed. In Scotland gabbro as well as granite is common in the ring-dikes. In New Hampshire the ring-dikes range in composition from monzodiorite through monzonite, syenite and quartz syenite to granite. In New Hampshire and Norway the rocks in the ring-dikes are alkalic.

Central Volcanics.—Eleven of the 30 ring-dike complexes that have been investigated for this paper have a central block of volcanics that has subsided. These central volcanics consist of flows and pyroclastic rocks; ranging in composition from basalt through andesite and trachyte to rhyolite, they are comagmatic with the rocks in the associated ring-dikes. These volcanics may occupy an area as much as 5 miles in diameter, but in most instances later intrusions have greatly reduced the area occupied by the volcanics. In some complexes, the volcanics are in direct contact with the ring-dike, but in others a belt of pre-volcanic rocks lies between the ring-dike and the volcanics themselves. The volcanics rest unconformably on these older rocks.

The volcanics dip inward toward the center of the complex. The dip is greatest near the ring-dike and becomes progressively less toward

the center. Near the ring-dike the volcanics may even possess a vertical dip and in rare instances they are overturned so that they dip outward. Toward the center of the volcanic area the volcanic rocks may be essentially horizontal. The best example of a central subsided block of volcanics is found at Glen Coe, Scotland (Clough, Maufe, and Bailey, 1909). In the United States, good examples of central volcanics are found in the Ossipee Mountains of New Hampshire (Kingsley, 1931) and the Quitman Mountains of Trans-Pecos Texas (Huffington, 1942).

Displacement.—Comparatively few data are available concerning the net-slip along the ring-fracture into which the ring-dike was intruded. In the Quitman Mountains of Texas the net-slip may not be much greater than 300 feet. In Mull the net-slip may be 3000 feet or more (Richey, 1932, p. 66). At Slieve Gullion, Ireland, there may have been no displacement along the ring-fracture (Richey, 1932, p. 99).

The central part of the volcanic block has always subsided more than that portion of the block near the ring-dike. In the Quitman Mountains the center of the volcanic block has subsided 4000 feet. In the Ossipee Mountains of New Hampshire, the subsidence of the central part of the volcanic block may be as great as 12,500 feet (Kingsley, 1931, p. 164).

Central Stock.—Seventeen of the 30 ring-dike complexes possess what may best be called a central stock. Actually the center of the stock is almost always eccentric to the center or centers of the associated ring-dikes. The average radius of these central stocks is 2.0 miles. One near Sylling, Norway, has a radius of 3.8 miles; a very elongate one at Percy, New Hampshire, has a major radius of 5.5 miles, a minor radius of 1.4 miles. The central stocks usually consist of quartz-bearing rocks, commonly quartz syenite or granite.

Screen.—A screen is a body of country rock lying between two ring-dikes or a ring-dike and a stock. Screens are common in Mull but are rare in Ardnamurchan. They are fairly common in New Hampshire.

Cone Sheets.—Cone sheets are dike-like bodies, arcuate in plan, that are concentric about the ring-dike centers. The thickness ranges from a few feet to a few tens of feet. Cone sheets dip about 45 degrees toward the center of the ring-dike complex, but the inner cone sheets dip more steeply than the outer ones. The Scottish cone sheets, if projected downward, meet at a focus about 3 miles beneath the present surface of the earth. It is commonly believed that cone sheets and

ring-dikes usually occur together. This idea has developed because of their association in the British Tertiary districts. Actually only 3 of the 30 ring-dike complexes possess cone sheets; these 3 are Mull, Ardnamurchan and Slieve Gullion (Richey and Thomas, 1932). Moreover, many cone sheets occur without any associated ring-dikes.

Vent Agglomerates.—Vent agglomerates fill passageways drilled through older rocks by explosive volcanic activity. In some instances the vent agglomerates form bodies that are arcuate in plan and thus seem to have been controlled by arcuate fractures. Vent agglomerates may form at almost any stage in the history of the ring-dike complex. Moreover, it is difficult in many instances to distinguish vent agglomerates from surface volcanic breccias (Bailey, *et al.*, 1924, pp. 195–210). Vent agglomerates are particularly common in Mull, Ardnamurchan and Arran; they have also been observed in the Quitman Mountains of Texas and the Belknap Mountains of New Hampshire.

Age.—Ring-dikes older than Devonian have not been described, but there is no reason why pre-Devonian ring-dikes should not be found. Devonian ring-dikes have been described from Scotland. The ring-dikes of New England and adjacent parts of Quebec are probably Mississippian. The ring-dikes of the Oslo region, Norway, are Permian. A Jurassic ring-dike has been described from California, and Tertiary ring-dikes occur in Scotland, Texas, Colorado, and Utah.

ORIGIN OF RING-DIKES

Original Interpretation.—It is generally agreed that the intrusion of a ring-dike is preceded by the formation of one or more steeply dipping annular fractures. There are, however, two additional fundamental problems. One concerns the forces involved in the development of the ring-fractures. The second concerns the question of the origin of the space occupied by the ring-dike. The most complete discussion of these problems is contained in papers by Anderson (1936) and Richey (1932). In fact, although geologists working in New Hampshire reached some conclusions that they considered to be at variance with the ideas of the Scottish geologists, subsequent reading showed that our conclusions are almost identical with those of Richey.

The original interpretation was evolved by E. M. Anderson, whose theory was first expounded in the Mull Memoir (Bailey, *et al.*, 1924, pp. 11–12) and elaborated in a subsequent paper (Anderson, 1936).

A magma reservoir with a diameter of several miles is assumed to

exist in the outer shell of the earth. The top of this reservoir is perhaps 4 to 5 miles beneath the surface of the earth at the time the ring-dikes form. The specific gravity of the magma is assumed to be equal to that of the surrounding rocks. Whenever there is an increase of pressure in this reservoir and the magma pushes outward, the surrounding rocks, because expanding, are subjected to tension. Tension fractures form perpendicular to the contact of the magma reservoir. If a cross section is visualized, the contact of the magma reservoir forms a parabola convex upward. The tension fractures, at right angles to this parabola, dip inward toward a common center, some distance below the top of the reservoir. Anderson points out that, even if actual fractures do not form, the surfaces perpendicular to the contact of the reservoir will be potential directions of weakness to be followed by any intrusions. These intrusions constitute the cone sheets.

On the other hand, if the pressure in the magma reservoir decreases, the surrounding rocks are subjected to tension. But the tension fractures under such conditions will be parallel to the contact of the reservoir. The outward inclination of such fractures is too low, according to Anderson, to be the ruptures occupied by ring-dikes. The ring-dikes, he believes, follow one of the two shear directions. Fractures following the steeper of the two possible shear directions would form a great arch. The block bounded by such a fracture, or fracture system, will have the shape of a paraboloid, convex upward. A potential cavity is formed between the country rock and the subsiding central block isolated by such a fracture. Magma welling up from the underlying reservoir fills this potential cavity as rapidly as it develops. After the magma has consolidated, the resulting igneous body will have the form of a cone opening downward, but the apex will be broad and round rather than sharp. Subsequent erosion of such a body produces an outcrop that is more or less circular in plan—that is, a ring-dike.

The essence of this hypothesis is that a ring-dike results from intrusion of magma into a potential cavity left between a subsiding block and stationary walls. The sides of the block must dip outward. The Scottish field geologists developed many subsidiary hypotheses which need not be elaborated here (Richey, 1932). This subsidence of a subterranean block constitutes underground cauldron subsidence.

In most instances in which the ring-fracture is essentially vertical and maintains its steep dip right up to the surface of the earth, volcanic rocks derived from the underlying magma reservoir have subsided within

the ring-dike. This results in what is known as surface cauldron subsidence. It will be recalled that such central volcanics are found in 11 of the 30 ring-dike complexes that have been studied. In other words, 35 per cent of the known ring-dike complexes represent surface cauldron subsidence. Anderson grants that he has not worked out the dynamics of this type (1936, p. 154).

Evidence from New Hampshire.—It became apparent as field work progressed in New Hampshire during the early 1930's that the hypothesis outlined above was not entirely satisfactory. In New Hampshire the contacts of the ring-dikes are essentially vertical. It is obvious that no cavity forms when a cylindrical block bounded by vertical walls subsides. It is also difficult to understand, on Anderson's hypothesis, what stops a block once it is isolated and starts to subside.

Vertical ring-dikes can be explained if we assume that the intrusion has been controlled by an annular vertical fracture zone, the width of which was comparable to the present width of the ring-dike. This fracture zone would be a place of weakness, very susceptible to piecemeal stoping. In some instances the stoping might proceed in the manner originally outlined by Daly, whereby small blocks settle in the magma to be assimilated at depth. On the other hand, many blocks might be carried along by magma moving upward along the fracture zone. The abundance of xenoliths, usually only a few inches across and partially assimilated, in the Albany quartz syenite, which forms some of the most conspicuous ring-dikes of New Hampshire, gives added weight to this hypothesis. The piecemeal stoping hypothesis also explains the irregularity of the contacts of some ring-dikes.

The importance of piecemeal stoping in the formation of ring-dikes was realized by New Hampshire field geologists during the years 1931 to 1934. J. E. Richey, who has had more experience with the ring-dikes of Scotland than anyone else, had already realized the possible importance of piecemeal stoping (1932, pp. 99 and 132).

There is another very interesting fact concerning the ring-dikes of New Hampshire. Although there are 15 ring-dike complexes and 41 ring-dikes, subsided central volcanics are found in only 5 of the complexes. Moreover, in every instance the ring-dike surrounding these subsided volcanics is composed of the same rock—the Albany quartz syenite. This indicates that surface cauldron subsidence occurred only at that stage in the evolution of the White Mountain magma series when the magma had evolved to a quartz syenite stage. Conversely, the

35 ring-dikes not composed of Albany quartz syenite were associated either with underground cauldron subsidence or with no subsidence. This subject is considered below.

ADDITIONAL MECHANISMS.—The Scottish geologists have suggested that in certain instances an arcuate block might be bounded by two essentially concentric ring-fractures that join; these fractures might be cut off upward by a horizontal fracture. An arcuate potential cavity would form if such a block were to subside. Intrusion of magma into the potential cavity, followed by consolidation and erosion, would result in an intrusive body arcuate in plan.

One argument advanced by the Scottish geologists in favor of this mechanism is the occurrence of "cappings" above some of the ring-dikes, notably the Beinn a' Ghràig ring-dike at Mull (Bailey, *et al.*, 1924, pp. 341–344), and dike A at Ardnamurchan (Richey, Thomas, *et al.*, 1930, pp. 285–286). There is also some evidence bearing on this subject in New Hampshire. In the mechanism developed by Anderson, a continuous ring-fracture occupying 360 degrees should be represented either by a ring-dike or a fault. At the south end of the Cape Horn ring-dike in the Percy area of New Hampshire, exposures of the older country rock are unusually good. It is apparent that there is no fault south of the ring-dike. Therefore, a mechanism involving the subsidence of a large, central, paraboloid block cannot be employed. The contacts of the Cape Horn ring-dike are relatively smooth, however, and it seems likely that the magma was emplaced by the subsidence of an arcuate block bounded by two arcuate fractures (Chapman, 1935, p. 419).

In some cases the magma may make room for itself by pushing apart the walls of a ring-fracture. This mechanism has been suggested to explain the concentric folds around the early granophyre at Mull (Bailey, *et al.*, 1924, pp. 168–169).

In some instances the intrusion of a ring-dike may be preceded by the introduction of vent agglomerates. In this case the older country rock is blown out. However, if the magma of the ring-dike occupies the space filled by the agglomerate we still must find some mechanism to make this exchange—either the magma pushes the vent agglomerate upward or to the side, or takes its place by piecemeal stoping.

The reasons why ring-dikes are usually arcuate, occupying only part of a circle rather than forming a complete circle, has been discussed by Billings (1942b, pp. 286–288) and Modell (1936, pp. 1925–1927).

ORIGIN OF RING-FRACTURES.—In the preceding paragraphs we have considered the mechanics of intrusion of ring-dikes. All hypotheses are similar in assuming that the intrusion is preceded by the formation of one or more ring-fractures. We have as yet not considered the forces involved in the development of these ring-fractures.

Anderson assumes that the ring-fracture forms when the magma in the reservoir is under reduced pressure. There are, however, several objections to this interpretation. Richey (1932, p. 134) has pointed out that it is difficult to conceive of magmatic pressure falling to such an extent that the roof rocks are subjected to tension. On the other hand, the mechanism recently described by Williams to explain such calderas as Crater Lake, Oregon, involves such a process. The magmatic pressure in the reservoir is reduced by the eruption of vast quantities of lava (Williams, 1942, pp. 101–107).

The contacts of most ring-dikes in New Hampshire are vertical. This is inconsistent with the outward dipping attitude deduced by Anderson in his analysis. Is it not much more likely that the ring-fracture is produced by magma pushing upward? Granite magma has a lower specific gravity than the solid older rocks into which the ring-dikes were intruded (Daly, 1933, p. 276). Under such conditions the granite magma would be constantly trying to rise, as Nettleton has shown in his analysis of the fluid mechanics of salt domes (Nettleton, 1934). Cone sheets form if the overlying roof-rocks fail by the formation of shear fractures (Billings, 1942b, p. 283). On the other hand, circular vertical fractures analogous to extension fractures may form (Billings, 1942, p. 103). Once a cylindrical block overlying the magma reservoir has been completely isolated from the surrounding rock by such a fracture it is then free to sink into the magma. Richey has also suggested that ring-fractures form when the magma is pushing on its roof (Richey, 1932, pp. 136–137).

IMPLICATION FOR STOCK INTRUSION

Clough, Maufe and Bailey (1909) discussed this problem in the Glen Coe paper. They pointed out that if a cylindrical fracture with a vertical axis were cut off upward by a subsurface horizontal fracture, the subsiding cylindrical block would not extend to the surface of the earth. The potential cavity left between the subsiding block and its roof would have the form of a cylinder. Intrusion of magma to this potential cavity would result in an intrusive body circular in plan and

possessing steep contacts. To this type of intrusion the term stock is usually applied. The mechanism just described has been called underground cauldron subsidence. Although this idea was proposed nearly thirty-five years ago, the mechanism has not been employed by American geologists. The Scottish geologists have applied it specifically to the Glen Cannel granophyre at Mull (Bailey, *et al.*, 1924, pp. 331–336) and the Mourne Mountains in northern Ireland (Richey, 1928). Many stocks of the White Mountain magma series in New Hampshire have probably formed in this way.

This hypothesis has some advantages over the piecemeal stoping hypothesis as an explanation of stocks. Both underground cauldron subsidence and piecemeal stoping are adequate to explain the discordant character of the contacts of stocks. The relatively smooth contacts characteristic of stocks have been difficult to understand on the piecemeal stoping hypothesis. Moreover, as many geologists have realized for years, xenoliths should be relatively common if piecemeal stoping were an important mechanism. Underground cauldron subsidence explains the rarity of xenoliths.

OTHER INTRUSIVE MECHANISMS

In thus emphasizing ring-dikes and cauldron subsidence in the present paper, the writer by no means wishes to imply that this is the only way in which intrusive bodies may be emplaced. Unfortunately, many geologists, after studying a few igneous bodies and deducing the mechanics of intrusion, have concluded that their hypothesis applied to all large igneous bodies throughout the world. They have failed to realize that other mechanisms might be equally important.

New Hampshire is an unusually good place to study contrasting intrusive mechanisms. Whereas the White Mountain series has been emplaced largely by cauldron subsidence, the older New Hampshire series has been emplaced chiefly by forceful injection. Magma under the influence of orogenic pressure has forced its way into the older country rock. Moreover, atomic replacement has also been locally important in New Hampshire in the formation of what we commonly call plutonic rocks.

SUMMARY

Our ideas about ring-dikes have been developed almost exclusively by Scotch geologists, notably J. D. Richey and E. B. Bailey. In the

present paper critical data concerning 115 ring-dikes in 30 different ring-dike complexes have been compiled. Ring-dikes are most extensively developed in the British Isles and in New Hampshire. The principles established by the Scotch geologists are applicable to New Hampshire. Although some modifications of the original theory were evolved independently in New Hampshire, subsequent reading of British publications showed that the same ideas were already in print.

The initial ring-fractures are essentially vertical extension ("tension") fractures due to the upward pressure of the magma. Some ring-dikes form when magma fills the potential cavity left between the walls and a subsiding block, the walls of which slope outward. Many ring-dikes, however, form when magma intrudes an annular fracture zone by piecemeal stoping. Although, in such a case, the block inside the ring-fracture may subside, this does not necessarily take place. Thus the formation of a ring-dike is not necessarily accompanied by cauldron subsidence. A few ring-dikes result from the subsidence of an arcuate block lying between two ring-fractures. In some instances ring-dikes have pushed apart their walls. Stocks may form when a potential cavity, left between the roof and a subsiding block, is filled by magma.

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SECTION OF PSYCHOLOGY

MARCH 15, 1943

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Personality Development and the Social Psychology of Peace.

In the struggle for democratic victory and lasting peace, the most serious bottleneck is not in the production of ships, tanks, airplanes or food, but in the production or training of more adequate personalities. This problem of psychological "production" exists both in the regions inhabited by the United Nations and, especially, in the countries dominated by Germany and Japan.

There is no longer time for leisurely debating about the question of so-called "cultural lags." It is pathetically obvious by this time that we are tremendously more efficient in coping with physical and chemical problems of transportation, agriculture, industry and physical health than we are in tackling biological, anthropological and psychological problems of human relations and personality development. The fact that we are up against such serious emergency problems in the present global crisis may actually be helpful in the long run. Some of the most important advances in science have been made through desperate attempts at coping with acute emergencies.

In the field of human relations, the basic and lastingly effective approach must be sought along the lines of prevention, instead of concentrating on essentially palliative treatment when the psychopathological condition is already upon us, so to speak. The problem is apparently one of preventive mental hygiene on a world-wide scale. Just as we managed to eliminate hampering superstitions and dogmas from sanitary engineering and medicine, so we must at once proceed to set up effective and enduring mental hygiene control of so-called political and economic problems. The combined biological, anthropological and psychological approach must try to accomplish here what physics and chemistry have done in the sheerly technological improvement of industry and transportation.

Though little is known from the standpoint of such scientific, largely psychological, control of human relations and personality development, that little is more than enough to start with—in comparison with the even more haphazard and obviously unsuccessful techniques of untrained persons. A little scientific knowledge of "human

nature" applied now or very soon seems a safer gamble than just standing by, hoping to apply a whole lot of it later on. If the specialists and professional workers refuse to tackle the job at once, simply because all the discoveries needed are not yet available, even more ignorant and psychologically less realistic amateurs will continue to insist on pinch-hitting for them. We may then never accomplish the job "later," due to the dangerously unsound and irrelevant fumblings of so-called "practical" persons and untrained reformers, however well-meaning, who lack the perspective of contemporary biology, anthropology and psychology. Ours is truly, or must speedily be turned into an era of scientific, essentially psychological, planning.

We already have a good deal of planning in the field of public health and public education. The question is not whether we should have a planned society, but what kind of sounder planning should we have. What kind of planned human relations, planned personality development, planned education and re-education for social change may be envisaged? How can such psychological plans, themselves subject to change, be expected to be improved realistically and imaginatively as we go along and keep making psychologically relevant further discoveries? Let us try to answer these questions: (a) what kind of personality "production" seems indicated for a lasting and progressively more democratic peace, according to relevant clinical and research findings; (b) what could be done immediately, starting from where we are, in order to make possible such personality "production," including continuous improvements and not easily anticipated modifications?

Psychological methods are now available and could be further improved: (a) for sizing up the quality and trend of existing personality development and human relations; (b) for improving the prevailing quality and trends; (c) for checking up from time to time on the progress of psychologically relevant improvements in personality "production" here and abroad. Of course, there is need for further work and discoveries.[2,3] Such work, geared to the needs of personality "production," should have priority over other kinds of experimental and clinical work for some time to come, even after the war. Just as industrial production can be co-ordinated and geared to the war effort, so the work and investigation of psychological specialists may be correlated more definitively from now on, with the help of such groups as the Society for Research in Child Development, the National Research Council, the

Society for Psychological Study of Social Issues, the National Committee for Mental Hygiene, the Social Science Research Council and others.

As an immediate starting point, we should aim for the global production of the kinds of personalities of all ages that are found now in Switzerland and Sweden, in the United States and England, in Canada and Australia—in contrast, say, to the kinds of personalities that are being produced now in Nazi Germany and similar countries. This means an inventory job of what we have on hand, to begin with.

What kinds of psychologically relevant differences could we expect to find to account for the personality characteristics and behavior trends of Swiss or Swedish boys in comparison with Nazi-educated German boys, of American or English girls in comparison with Nazi-indoctrinated German girls? It is unlikely that tests of visual acuity or memory, or tests of general intelligence and special aptitudes would reveal significant differences between the general populations living under such contrasting social orders.

We *could* expect significant group differences in such dimensions of personality as flexibility-rigidity, objectivity-subjectivity, directness-indirectness, emotional stability-volatility, dominance-submissiveness, and optimism-pessimism. Even at cursory inspection we could grossly expect that a Nazi-disciplined youngster or youth would very probably be much more rigid, much less objective, much more submissive toward persons of authority and much more aggressively domineering toward social "inferiors" or weaker persons than a Swiss or Swedish boy of comparable age, intelligence and educational background. He would probably also show characteristic varieties and fluctuations of behavior in other personality dimensions, in given behavior-sampling situations or interpersonal relationships.[2,5,6]

In addition to such "horizontal" differences at any given point of growth, certain developmental differences can also be gauged "vertically" as differential rates of social-emotional maturation. From infancy through adolescence, in given Western societies, the trend is broadly from excessive initial dependence to increasing self-reliance, from narcissistic and clannish self-centeredness to increasing objectivity, from emotional explosiveness and impulsive hostility release to greater self-control, more flexible frustration-tolerance and more constructive substitute-gratifications, from extreme infantile jealousy and competitiveness to relatively greater readiness for friendly team-work and affectionate mutual aid.[3] Research findings suggest that children

reflecting more authoritarian adult influences display a slower increase of self-reliance in moral reasoning. In child groups subjected to autocratic leadership, impulsive aggressiveness markedly increases, while behavior indices of friendly mutual aid and team spirit show a decrease, along with diminishing constructiveness, objectivity and self-reliance. The opposite apparently happens in more democratically "led" or handled groups, just as clinical findings show greater all-round self-reliance in children exposed to relatively lesser degrees of adult domination.

In the case of adult personalities, such developmental trends may be similarly gauged. Differential rates of increase in presenile social-emotional involution and in regressions produced by severe frustrations can be expected. Such differential rates of adult personality development are reflected in sympathetic identification with, or active participation in, the Ku Klux Klan or lynching mobs, the Father Divine movement or the Townsend movement, etc. More rigid frustration-tolerance can result in extreme forms of conservatism *or* radicalism—in too rigidly resisting any social change whatever or in too rigidly insisting on particular, perfectionistically unrealistic, notions of social change. The point is that, while in the United States a Ku Klux Klan type of social movement remains relatively insignificant, in adult Nazi Germany it actually manages to become the dominant culture pattern.

In relating the differential rates of social-emotional maturation of children to those of adults, two further findings are important. On the one hand, childhood experiences partly determine adult personality organization. On the other hand, institutional patterns such as family relationships, school relationships or industrial relationships also partly determine the individual's state of mental health and social-emotional retardation.

We can then meaningfully ask: What environmentally manipulable and already manipulated influences produce the Swiss boy or the Swedish boy, the American or English adult, in comparison with what we get in the case of countries like Nazi Germany? How can we even further improve the former, how can we modify or re-educate the latter, with the Swiss or Swedish, the American or English examples as minimal standards for international, preventive mental hygiene?

The direction of more and more democratic personality "production" can now be gauged pretty well. It amounts essentially to this: autocratic or excessively authoritarian power-relationships must be

curbed or eliminated throughout the life-span, and throughout the globe, in all basic interpersonal relationships between parents and children, teachers and pupils, employers and employees, public officials and citizens. In family life, in school life, in factories, courts, churches and hospitals, the individual's need and readiness for more secure freedom, privacy and self-reliance, for status and self-respect, for a feeling of belongingness and team spirit must be given ever more leeway. This is in keeping with the basic principles and methods of modern child guidance, progressive education, general mental hygiene and free inquiry in science.

Continued progress is needed in these matters even in the more democratic countries themselves. In addition, steps must be taken to spread these principles and methods of child education and adult education to the Nazi-indoctrinated and Nazi-dominated countries, regardless of the difficulties involved.

In postwar reconstruction programs, the Wilsonian principle of self-determination ought to be limited by such minimal requirements of international public health and mental hygiene. Complete and premature local self-determination is not sound to introduce or rely on everywhere, as long as it can result in a Nazi Germany and in the kinds of personality which are being turned out by its "education for death."[6] Transplanting and nursing along, for several decades or even longer, methods of representative government, progressive education and mental hygiene in family and industrial life, curbing economic and political nationalism in its manifestations on all age-levels, throughout the life-span—these are all minimal conditions for the accelerated production of more adequate and democratic personalities and cultures everywhere. If this can be considered turning Europe or other global regions "into a kindergarten," then we need more and better conducted nursery schools and kindergartens, both literally and figuratively speaking.[4] Any other approach is apparently doomed to failure, to judge from the basic fact of two world wars within one generation.

It is obvious now that it is very unsound and dangerous to plan the peace chiefly or even exclusively from an economic and military standpoint, instead of gauging the political, economic and military problems from these basic mental hygiene aspects of psychological reconstruction. This means that a great number of government personnel in the United Nations, members of congress, farmers, business and labor leaders ought to be made familiar at once with these perspec-

tives afforded by modern biology, anthropology and psychology. Perhaps more physicians, psychiatrists, psychologists, social workers, educators, engineers and scientists in general ought to enter politics at once. To insure such minimal mental hygiene standards in public thinking, standards of personnel selection ought to be immediately raised, from a psychological and psychiatric viewpoint, with reference to both appointed and elected officials. It is doubtful, for instance, that the late Sen. Huey Long would have passed such criteria of personnel selection—any more than Hitler or Mussolini; and there are, unfortunately, still others, even within the United Nations. The common man and the psychological specialists cannot afford to take chances on "letting George do it" any longer, since George keeps doing it to all of us with terrifying ignorance and frequently psychopathic perseverance, even in the more democratic countries.

If the common man in the democracies were given a more adequate understanding of the terrible acuteness of these problems and tasks, the psychological specialists might be soon given a far greater opportunity for applying to so-called "purely" economic and political problems the plans and techniques based on the most relevant findings of biology, anthropology and psychology. The common man, whether government official, businessman, farmer or workingman, is not able directly to tackle the problem of building better houses or bridges, or of the prevention and treatment of typhus. But, once assured that expert knowledge is available, the common man could see to it that the proper specialists be called in on the job, instead of more or less well-meaning, untrained amateurs. While the common man is rather helpless in directly tackling highly specialized tasks in the field of human relations and personality development, the specialists cannot undertake and execute such projects without the active consent and support of the untrained majority. The common man needs the psychological specialist, and *vice versa*.

This means a quick yet sound job of translating and communicating with the common man—more intelligibly, more convincingly than ever before. It is a problem of much more effective communication and hastened adult personality development even within the democratic countries. The principles, results and methods of free inquiry embodied in the sciences of biology, anthropology and psychology must be quickly made to help the common man help himself, before it is too late.

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SECTION OF ANTHROPOLOGY

MARCH 22, 1943

PROFESSOR G. EVELYN HUTCHINSON, Osborn Zoological Laboratory, Yale University, New Haven, Conn. *Food, Time, and Culture.*

It is generally possible to study any system S in two ways, (a) the *hololological*, in which matter and energy changes across its boundaries are studied; and (b) the *merological*, in which the behavior of individual systems of lower order composing S are examined. In the first instance, the behavior of S can be interpreted, if desired, in terms of an abstract mean member $\bar{s}$ of the class s_i, ($\bar{s}$, however, may have inconsistent properties). In the second case, the behavior of S is often predicted in terms of the aggregate Σs_i. Usually both methods are interwoven in any investigation, but the concept of a nation developed from the study of international politics, trade and finance would correspond to (a); that developed from a study of human behavior of individual members of the nation to (b).

The definition of S may be entirely arbitrary, or in terms of natural boundaries. The definition of a natural boundary with respect to any property is given as follows: When along any line drawn across the area under investigation any property p is found to vary with x, the length of the line measured from any arbitrary origin, the line is said to cross a natural boundary at any value of x for which p is discontinuous, or for which $\frac{dp}{dx}$ is maximal or minimal. Considering any set of properties p_i, $\frac{dp_1}{dx} \cdots \frac{dp_n}{dx}$ are not necessarily maximal or minimal for the same values of n; for different purposes the natural boundaries are different.

Biological communities have been studied in various ways. The extreme hololological approach may be applied in examination of the *total mass of living matter per unit area*, and the closely related *ecological photosynthetic efficiency* of a community. Evidence exists that if, starting with a barren area, either on land or covered by inland water, there is a slow but accelerating increase in the total biomass, then an inflection in the growth rate and finally an approach to a maximum level (stage equilibrium of Lindeman) which in nature may be maintained for centuries and which presumably is determined geochemically (by H_2O, P, etc.).

Merologically the characters of a community may be considered in various ways, of which one is a study of the frequency of occurrence of species, or probabilities p_1, p_2, p_3, . . . that any organism taken from the community belongs to given members of a set of species a_1, a_2, a_3 . . . The number of species of probability in excess of some given value defines the *diversity* of the community.

It appears that the diversity increases with the biomass initially, then reaches a maximum, probably before the maximum in the biomass, and decreases later. There is evidence that throughout stage equilibrium the probabilities for individual species vary, though the diversity may not.

The whole community can be regarded holologically as characterized by at least the following quantities, varying with respect to time: the *biomass*, the *diversity*, and a *set of probabilities* relating to particular species. Variation in the biomass differs from that of the others in that antecedent states determine subsequent states.

A single non-human species shows comparable increase in biomass with time, but nothing that corresponds to diversity or probability sets, even in the most developed social insects.

If there is an analogy between a biological community and a human society, as has often been maintained, it should be possible to find properties of the latter, formally equivalent to the biomass, the diversity and the sets of probabilities.

If a series of biological communities, delimited by *natural boundaries*, and in equivalent stages of development and in the same geographical and climatic region be compared, the same specific combination of the biota need not be expected, because more species may have high probabilities of occurrence than there are spaces to fill. Similarly various aspects of culture differing from group to group may, under defined conditions, be regarded as having definite probabilities, p_i, of occurrence.

The diversity of the community may be regarded as equivalent to the rather vague ideas that inevitably arise from comparison of more complex and less complex cultures. In a given case, a gradual transformation in every cultural element studied merologically is conceivable, without the holological value of the complexity being changed.

It is more difficult to find an analogy to the concept of the biomass. The biomass is, however, particularly important, because it alone in the biological community has causal continuity. It is clear that the population composing a human society is involved in the analogy. Moreover, as in a biological community, causal continuity is not dependent

on genetic continuity. There is also a continuity of culture that is historically determinative, and so behaves like the biomass. If we regard each individual as handing down cultural tradition to the next generation in a constant population, the total quantity Q of the culture at any time may be regarded as the product of the number of individuals N and an intensity factor I.

This concept appears artificial when viewed from the standpoint of a single culture, but may have an application when cultural contact has been established. There is a difficulty, however, that there is obviously also a quantity analogous to the partition coefficient involved here. This quantity M is vectorial, however, and may be taken as unity when no barrier exists. Thus in the suburbs of Ootacamund, the existence of numerous suburban villas, built by retired Indian civil servants of British birth, among rhododendrons and gorse bushes, has no effect on the architecture of the Todas ($M_{BT} \rightarrow 0$). But in Portuguese India, where a deliberate effort was made to reduce the partition coefficient, the presence of the Portuguese had an extraordinary effect on Hindu temple architecture. Considering the *architectural* tradition of this region ($M_{PH} \rightarrow 1$), since the Hindu population was much larger then the Portuguese, it is clear that the intensity factor was much greater in the Portuguese than in the Hindu population, owing in part to military and commercial prestige. But if the *religious* tradition be considered, this is not necessarily true, because the temple plan, as far as can be ascertained, is still fundamentally Hindu. It is probable that the function involved in cultural contact is not linear on N, but presumably, in the direction A to B, for some particular phase of culture, the effect of A on B has the form $f\left(\frac{N_A I_A}{N_B I_B} M_{AB}\right)$ per unit I_B.

It is suggested that the problems of history and archaeology can be reformulated in terms of general variables Q, I, C, M, and p_i.

The theory might be developed in terms of alternative sets of differential equations. At present, the observational data are in general nonmetric. It is not inconceivable, however, that in a large number of cases the deductions from possible theoretical alternatives can be compared in the form of relationships of *less than* or *greater than*, or geometrically in the topological form of inside or outside, which can be checked with the observational data. Relationships of this sort may give an opportunity to introduce a quantified theory into nonmetric sciences.

SECTION OF BIOLOGY

March 13, 1943

Conference on *"Parasitic Diseases and American Participation in the War."*

The Section of Biology held a Conference on "Parasitic Diseases and American Participation in the War," as the third in the series for the Academic Year of 1942–1943. Doctor Horace W. Stunkard, New York University, New York, N. Y., President of the Academy, was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

"Introductory Remarks," by Horace W. Stunkard.

"Current and Post War Problems Associated with Human Protozoan Diseases," by Lowell T. Coggeshall, School of Public Health, University of Michigan.

"Changed Viewpoints on Helminthic Disease: World War I vs. World War II," by Norman R. Stoll, Rockefeller Institute.

"Arthropod Vectors of Animal Parasites of Primary Importance in the Present War," by Robert Matheson, Cornell University.

"Clinical Features of Parasitic Diseases and their Consideration in Military and Naval Operations," by Thomas T. Mackie (Lt. Colonel), Army Medical School, Washington, D. C.

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ELECTED MARCH 25, 1943

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